Claims

1. A quaternary or higher group IB-IIIA-VIA alloy having the general formula (I):

$$A(B_{1-x}C_x)(D_{1-y}E_y)_2 \;\ldots\ldots\; (I)$$

wherein:

A is a group IB element;
B is a group IIIA element;
C is a group IIIA element, which is different to B;
D is a first group VIA element (hereinafter referred to as VIA_1);
E is a second group VIA element (hereinafter referred to as VIA_2); and
each of x and y independently are from 0 to 1, provided that both x and y are not zero at the same time;

and the alloy being characterised by an x-ray diffraction pattern (XRD) having a main [112] peak at a 2θ angle ($2\theta_{(112)}$) of from 26° to 28° for Cu radiation at 40kV, wherein a glancing incidence x ray diffraction pattern (GIXRD) for a glancing angle of from 0.2° to 10° reflects an absolute shift in the $2\theta_{(112)}$ angle of less than 0.06°.

2. The alloy of claim 1, wherein the alloy has a crystal structure comprising a lattice of unit cells, wherein all crystallographic planes of the unit cells show a variance in d-spacing of less than 0.01Å.

3. The alloy of claim 1, wherein the element concentration of elements A, B, C, D and E, as characterised by XPS depth profiling, is substantially uniform through the alloy.

4. The alloy of claim 1, wherein A is Cu, B is In, C is Ga, D is Se and E is S, the alloy having a formula (II):

$$Cu(In_{1-x}Ga_x)(Se_{1-y}S_y)_2 \quad \ldots\ldots \quad (II)$$

5. The alloy of claim 4, wherein x is from 0.25 to 0.3 and y is from 0.05 to 0.8

6. The alloy of claim 4, wherein the x-ray diffraction pattern (XRD) has a main [112] peak at a 2θ angle ($2\theta_{(112)}$) of from 26.9° to 28° for Cu radiation at 40kV, taken at a d-spacing of from 3.3117Å to 3.1840Å.

7. The alloy of claim 4, wherein the GIXRD for a glancing angle of from 0.2° to 10° reflects an absolute shift in the $2\theta_{(112)}$ angle of less than 0.01°.

8. The alloy of claim 4, wherein the alloy has a crystal structure comprising a lattice of unit cells, wherein all crystallographic planes of the unit cells show a variance in d-spacing of less than 0.001Å.

9. The alloy of claim 6, wherein the main [112] peak is from a 2θ angle of from 27.0° to 27.5°.

10. The alloy of claim 6, wherein the main [112] peak is substantially symmetrical.

11. The alloy of claim 4, wherein the alloy has a band gap that can be shifted from 1 eV to 2.4 eV.

12. The alloy of claim 11, wherein the alloy has a band gap that can be shifted from 1.1 eV to 1.5 eV.

13. The alloy of claim 4, wherein the S content, as expressed by the molar ratio of $\frac{S}{(S+Se)}$, is from 0.05 to 0.7.

14. The alloy of claim 1, wherein A is Cu, B is In, C is Ga, D is Se and y = 0, the alloy having the general formula (III)

$$Cu(In_{1-x}Ga_x)Se_2 \quad \ldots\ldots\ldots(III)$$

15. The alloy of claim 14, wherein x is from 0.25 and 0.3.

16. The alloy of claim 14, wherein the alloy has a crystal structure comprising a lattice of unit cells, wherein all crystallographic planes of the unit cells show a variance in d-spacing of less than 0.006Å.

17. The alloy of claim 14, wherein the x-ray diffraction pattern (XRD) has a main [112] peak at a 2θ angle ($2\theta_{(112)}$) of from 26.80° to 27.0° for Cu radiation at 40kV, taken at a d-spacing of from 3.3236Å to 3.2990Å.

18. The alloy of claim 14, wherein the GIXRD for a glancing angle of from 0.2° to 10° reflects an absolute shift in the $2\theta_{(112)}$ angle of less than 0.05°.

19. The alloy of claim 17, wherein the main (112] peak lies from a 2θ angle of from 26.85° to 26.9°.

20. The alloy of claim 17, wherein the main (112] peak is substantially symmetrical.

21. The alloy of claim 14, wherein the alloy has a band gap which can be shifted from 1.1 eV to 1.2 eV.

22. The alloy of claim 21, wherein the alloy has a band gap which can be shifted from 1.15 eV to 1.18 eV.

23. The alloy of claim 14, wherein the Ga content, as expressed by the molar ratio of $\frac{Ga}{(Ga+In)}$ is from 0.25 to 0.3.

24. The alloy of claim 1, wherein A is Cu, B is In, D is Se, E is S and x = 0 and has the general formula (IV):

$$CuIn(Se_{1-y}S_y)_2 \quad ..... \quad (IV)$$

25. The alloy of claim 24, wherein y is from 0.1 and 0.5.

26. The alloy of claim 24, wherein the alloy has a crystal structure comprising a lattice of unit cells, wherein all crystallographic planes of the unit cells show a variance in d-spacing of less than 0.007Å.

27. The alloy of claim 24, wherein the x-ray diffraction pattern (XRD) has a main (112] peak at a 2θ angle ($2\theta_{(112)}$) of from 26.80° to 27.3° for Cu radiation at 40kV, taken at a d-spacing of from 3.3236Å to 3.2640Å.

28. The alloy of claim 24, wherein the GIXRD for a glancing angle of from 0.2° to 10° reflects an absolute shift in the $2\theta_{(112)}$ angle of less than 0.06°.

29. The alloy of claim 27, wherein the main (112] peak lies from a 2θ angle of from 27.0° to 27.2°.

30. The alloy of claim 24, wherein the alloy has a band gap which can be shifted from 1.05 eV to 1.23 eV.

31. The alloy of claim 30, wherein the alloy has a band gap which can be shifted from 1.15 eV to 1.20 eV.

32. The alloy of claim 24, wherein the S content, as expressed by the ratio of $\frac{S}{(S+Se)}$ lies from 0.1 and 0.5.

33. A semiconductor film comprising a film of an alloy of claim 1.

34. The semiconductor film of claim 33, wherein the alloy of claim 1 is deposited onto a substrate which serves as a support for the alloy.

35. The semiconductor film according to claim 33, wherein the alloy is in the form of a film having a thickness of 1.5 to 2.0 μm.

36. A photovoltaic cell including a semiconductor film of an alloy of claim 1.

37. The photovoltaic cell according to claim 36, wherein the photovoltaic cell has a conversion efficiency of from 8 to 15%.